(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 194 861
A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 86301745.5

(22) Date of filing: 11.03.86

(51) Int. Cl.[4]: G 06 K 11/06

(30) Priority: 11.03.85 US 710080

(43) Date of publication of application:
17.09.86 Bulletin 86/38

(84) Designated Contracting States:
AT BE CH DE FR GB IT LI NL SE

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(54) Electrographic touch sensor with z-axis capability.

(57) An electrographic touch sensor having Z-axis capability. In one embodiment, a uniform resistive coating (30) is applied to one surface of a substrate (12) and within this coating (30) orthogonal electrical fields are produced. Overlying the resistive coating is a flexible sheet (40) having a conductive layer, and interposed between the resistive coating and the conductive layer is an array of a material (32) having a substantially greater resistivity than that of the resistive coating (30). A Z-axis coordinate of a touched point on the sensor, related to the pressure force applied, can be obtained. This Z-axis coordinate is related to the change in the effective contact resistance between the resistive coating and the pick-off sheet caused by the pressure/force, and that change is "enhanced" by the high resistance array and thereby enables different values of pressure/force to be determined.

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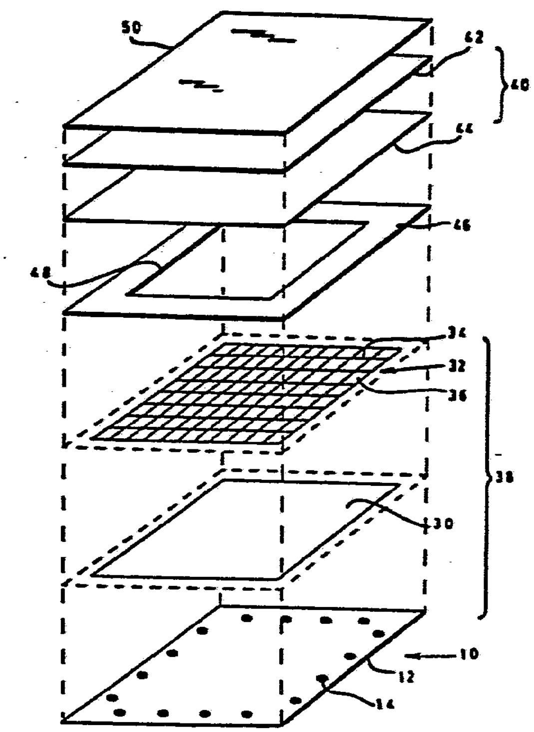


Fig. 3

Description

ELECTROGRAPHIC TOUCH SENSOR WITH Z-AXIS CAPABILITY

The present invention relates to devices for encoding or determining the coordinates of a location in a multidimensional system, and more particularly to an electrographic touch sensor whereby such points can be determined or selected and whereby a signal can be generated relative to the pressure/force applied at the particular point.

There are many fields of technology where it is desirable to generate electrical signals that are proportional to some physical point in a multidimensional coordinate system. For example, it is often desirable accurately to reconstruct graphs or other technical data representation to store such data in computers, or to process such data in a particular manner.

A device which has come into use for this purpose is known as an electrographic touch sensor wherein orthogonal electrical fields are produced; one in an X direction and one in a Y direction in a coordinate system. Contact of a sensor at a specific location with a finger or other object causes the generation of a signal that is representative of the X- and Y-coordinates of that particular point.

Orthogonal X and Y electrical fields of devices of this type have been generated by numerous types of systems. For example, parallel electrodes have been placed on opposite edges on each of two spaced apart sheets. The electrical potential in one direction is generated in one sheet with a voltage supplied to one set of electrodes, and the orthogonal field generated in the second sheet is produced in a similar manner. In another configuration, the orthogonal electrical fields are generated in a single sheet with various configurations of electrodes along the edges of the sheet, and the potential is applied to these electrodes in a proper timed sequence. One group of single sheet sensors utilize resistive type electrodes in contrast to another group that utilize diodes at each electrode.

There are other applications for touch sensors where information other than just coordinates of a point are to be selected or determined. For example, it is frequently desired to take some action by equipment based upon a selected pressure/force applied to the sensor. Typically this can be utilized to move a cursor to a specific position on a display screen and cause execution of a function as a result of additional applied pressure/force.

One sensor system that is known to accomplish at least a portion of such action is described in U.S. Patent No. 3,798,370, issued to G. S. Hurst, on March 19, 1974. In that patent is described a sensor for generating signals corresponding to the X- and Y-coordinates of a point. In addition, the probe provided for contacting the sensor to determine those

signals has a pressure switch therein whereby the output signals are transmitted to associated equipment only when sufficient pressure is applied to the sensor via the probe to close the switch. This device, however, does not produce a signal related to the value of the pressure.

A sensor having built-in capability to determine pressure or force directed against the sensor is described in U.S. Patent No. 4,198,539, issued to W. Pepper, Jr., on April 15, 1980. In that patent, a "switch" layer, whose resistance varies as a function of pressure, is added as a separate layer to the sensor. This extra layer, having conductive plates separated by carbon granules, is electrically separated from the resistive layer in which the orthogonal fields are produced. This construction is shown in Figure 12 and described in Column 9 of the patent. Such structure complicates the construction of a sensor by adding two or three more layers and thus significantly adds to the cost of producing the sensor.

It will be recognized that there are numerous pressure sensitive switches that could substituted for the separate layer as used by Pepper. Typical of these switches are described in U.S. Patents 4,314,227 and 4,315,238 issued to F. Eventoff on February 2, 1982 and February 9, 1982, respectively. These switches employ two conductive layers with a pressure sensitive semiconductor composition positioned therebetween.

A first aspect of the present invention provides an electrographic sensor for generating signals corresponding to the two dimensional coordinates of a

contact point on the sensor, the sensor being capable of generating signals related to the pressure/force applied at the contact point, and comprising:

1) a resistive sheet and a further sheet positioned proximate each other, such that the perimeter of the further sheet substantially conforms to the perimeter of the resistive sheet, and such that inner surfaces of the sheets face each other, each of the sheets

a) being capable of having electrical fields introduced therein, and

b) extending across the sensor,

and the further sheet being adapted to move towards the resistive sheet upon the application of pressure/force, to the sensor, at the contact point;

2) means for generating orthogonal electrical fields within the sensor, in the X and Y directions, such that signals corresponding to the X- and Y-coordinates of the contact point are produced when electrical connection is made between the sheets at the contact point; and

3) enhancing means interposed between the sheets, which determines an effective contact resistance between the sheets which varies inversely with the pressure/force applied, in a manner which differentiates between levels

of pressure/force applied at the contact point such that a signal corresponding to the Z-coordinate can be obtained, the Z-coordinate-signal being related to the magnitude of the pressure/force at the contact point.

A second aspect of the present invention provides an electrographic touch sensor for generating signals corresponding to the two-dimensional coordinates of a contact point on the sensor, the sensor being capable of generating signals related to the pressure/force applied at the contact point, and comprising:

1) means for generating orthogonal electrical fields within the sensor having

   a) a uniform resistive layer, to accept voltages to produce the orthogonal fields, and

   b) at least one exposed surface, the field-generating-means being adapted to generate the output signals of two-dimensional coordinates of the contact point when the sensor is contacted;

2) an array of high resistance material applied to the exposed surface of the field-generating-means, and having a resistivity substantially greater than the resistivity of the resistive layer of the field-generating-means, the array having a

predetermined configuration and covering a predetermined portion of said exposed surface; and

3) a conductive sheet which is preferably flexible, having a first surface and a further surface, positioned proximate said array with its first surface towards the array;

whereby when a pressure/force is applied to the sensor at the contact point it causes the first surface of the conductive sheet to make contact with the array and thereby generates signals corresponding to the two-dimensional coordinates of the contact point, and a signal corresponding to a third coordinate, which third coordinate is related to a change of the effective contact resistance between the resistive layer of the field-generating-means and the conductive sheet at the contact point, as enhanced by the array.

A third aspect of the present invention provides an electrographic touch sensor for generating signals corresponding to the X- and Y-coordinates of a contact point on the sensor, and being capable of generating signals related to a pressure/force related Z-coordinate of the contact point, which comprises:

1) a substrate;

2) a uniform resistive coating applied to the substrate;

3) electrode means in contact with the resistive coating proximate the perimeter edges of the

coating, whereby orthogonal electrical fields can be geherated in the coating upon the application of voltages to the electrode means;

4) an array of material applied to the resistive coating, having a resistivity substantially greater than the resistivity of the resistive coating, and having a selected configuration; and

5) a flexible conductive sheet, having a first surface and a further surface, proximate the array with said first surface towards the array;

whereby when a sufficient pressure/force is applied to the further surface of the conductive sheet at the contact point it causes contact of the first surface of the conductive sheet with the array of material and thereby generates signals in the conductive sheet corresponding to the two-dimensional coordinates of the point, and independently generates a signal in the conductive sheet corresponding to a reduced contact resistance between the first surface of the conductive sheet and the resistive coating, which is a function of the pressure/force applied at the contact point and is thus a function of the third coordinate.

A fourth aspect of the present invention provides a method for obtaining a signal corresponding to the pressure/force applied to an electrographic touch sensor at a selected contact point, the sensor comprising a pair of closely disposed layers, at least

one of which comprises a resistive layer having a uniform resistivity value; the sensor being adapted to provide signals corresponding to the X- and Y-coordinates of the contact point, the method comprising:

1) applying a distributed array of an enhancing material between the layers, the resistivity of the material of the array being substantially greater than the resistivity of the resistive layer;

2) generating orthogonal electrical fields in the sensor;

3) obtaining signals generated in the layers corresponding to such X- and Y-coordinates upon applying such pressure/force at such selected point; and

4) obtaining a further signal, generated during a separate time interval, related to a change in effective contact resistance between the layers upon application of the pressure/force at the contact point, the further signal increasing as a function of the pressure/force applied to the sensor at the point as the effective contact resistance is reduced upon an increase in the pressure/force.

The present invention produces an electrographic touch sensor for generating signals corresponding to the X- and Y-coordinates of a point, and further provides means for generating a signal corresponding to specific

pressure/force in the Z-direction on the sensor at that point.

The invention also provides a three-dimensional touch sensor having a reduced number of layers as contrasted to the aforementioned U.S. Patent No. 4,198,539, and a touch sensor wherein the effective resistance of the sensor decreases as a function of force/pressure in a manner to differentiate between various values of force/pressure.

According to the present invention, there is provided a sensor unit for generating signals representing the X- and Y-coordinates of a contact point. This sensor utilizes conventional one or two resistive sheet construction and is formed using generally conventional technology. Certain embodiments of the invention comprise a single resistive sheet and a conductive second sheet that is used for contacting the resistive sheet. In these and other embodiments electrodes are in contact with the resistive sheet or sheets, and voltages are applied to appropriate groups of the electrodes attached to the resistive sheets to produce orthogonal electrical fields in the resistive sheet(s).

Interposed between the two sheets of the sensor of the present invention is a layer of an "enhancing" material. As used herein, an enhancing material is a material which affects the effective contact resistance between the sheets. In embodiments of the invention the enhancing material decreases the effective contact resistance between the sheets at a substantially reduced relationship with respect to the applied pressure. In this way there is a substantial

difference in the effective contact resistance at differing pressures, which is sufficient to differentiate between those pressures. In preferred embodiments of the sensor the enhancing material has a resistivity substantially greater than the resistivity of the sheet(s). The enhancing material can be chosen from a variety of compositions, including, for example, compositions considered to be insulators. Furthermore, a variety of spacial distributions of these materials can be utilized.

The sensor is preferably provided with circuitry connected to the sensor to determine the X-and Y-coordinates of a point contacted on the sensor, (the contact point) as well as the pressure/force applied at that point.

Features of preferred embodiments of sensor according to the first aspect of the invention are now described. One or both of the resistive and further sheets may be elastomeric. The sensor may be provided with a layer of an elastomer on its outer surface. In one particular embodiment the layer has an exposed surface and an overlay sheet is provided juxtaposed against the exposed surface of the elastomer layer. The resistive sheet is preferably provided with a resistive coating on its inner surface, particularly a coating of preselected uniform resistivity, and preferably electrodes are provided in contact with the resistive coating for receiving voltages. Those electrodes comprise a plurality of contact electrodes, spaced along the periphery of the resistive sheet, and in contact with the resistive coating. Where the resistive sheet has a resistive coating, it is

preferred that the inner surface of the further sheet is conductive. In other embodiments each of the sheets is provided with a resistive layer on its inner surface, and with electrodes positioned along opposite edges of the sheet in contact with the respective resistive layers, the electrodes of one of the resistive sheets being oriented orthogonally with respect to the electrodes of the other sheet.

Where reference is made in the specification to a resistive layer, it may be a coating or any other type of layer. In some embodiments according to the invention the resistive layer on one or both of the sheets has a resistivity, preferably a uniform resistivity, in the range of 50 to 20,000 ohms per square. Such sensors are preferably used with an enhancing means comprising a grid array of resistance material having a resistivity greater than 30K ohm-cm.

In the sensor according to the second aspect of the invention, it is preferred that the means for generating the orthogonal electrical fields comprises a layer of uniform resistivity, provided with spaced-apart electrodes in contact with the layer, arranged along the perimeter of the layer, and adapted to receive voltages, the resistive layer being applied to a supporting substrate.

In embodiments of sensor according to the invention which comprise an array of high resistivity enhancing material applied to a resistive coating, particularly in sensors according to the third aspect of the invention, the array may take many forms. For example, it may comprise perpendicularly oriented lines of high

resistivity material defining rectangular open areas between said lines, or a resistance layer provided with substantially circular openings, or a distribution of an insulator material.

Features of preferred embodiments according to the third aspect of the invention are now described. The sensor may further comprise: voltage supply means; sequencing means for connecting the voltage supply means to the electrode means to generate the orthogonal fields in said uniform resistive layer; circuit means for receiving and processing the signals introduced into the conductive sheet corresponding to the X- and Y-coordinates of the contact point; and further circuit means for receiving and processing the signal introduced into the conductive sheet corresponding to the pressure/force and thus to the Z-coordinate of such contact point. The flexible conductive sheet may comprise an insulative flexible, preferably elastomeric, cover sheet positioned with a conductive layer on the side facing the array. The electrode means may comprise

(a) a plurality of contact pads spaced along each of said perimeter edges;

(b) a plurality of diodes, each of said diodes having a first lead connected to one of said contact pads and a further lead;

(c) trace leads connected to appropriate of said further diode leads; and

(d) terminals on said trace leads for the application of said voltages to said contact

pads for said generation of said orthogonal electrical fields in said resistive coating.

Alternatively, the electrode means may comprise:

(a) a plurality of contact pads spaced along each said perimeter edges;

(b) a resistor array proximate each of said perimeter edges having terminals for the application of said voltages; and

(c) leads connecting each of said contact pads to a selected point along said resistor array whereby selected voltages are applied to said contact pads upon application of said voltages to said resistor arrays for said generation of said orthogonal electrical fields in said resistive coating.

A number of types of enhancing material can be used in the present invention. For example, an "array" of material having a resistivity typically more than 1000 times that of the resistive sheet or of the resistive layer(s) can be used.

Another type of enhancing material is a distribution of materials normally considered to be insulators (having a very, very high resistivity). This distribution of particles can be applied to either of the sheets of the sensor, or to the resistive layers thereon so that contact must be made in between these particles. This distribution can be created by carefully positioned insulator bumps or beads up to about 0.025 in.,

randomly distributed powder, or by a rough resistive surface which provides high resistance bumps. Alternatively, an insulating surface coating that has a large fractional area of pin holes can be used. These effects are substantially enhanced by selecting a substrate material or contact sheet material, or both, which is elastomeric so that these sheets tend to extrude around the insulating particles, and the insulating particles tend under pressure to retract into the elastomeric sheet(s).

Still another type of "enhancer" is composed of a thin solid film of material which has a very high resistance in bulk, such as a lacquer paint. This must be applied in a very thin layer, e.g., five hundred to five thousand Angstroms, so that it is possible to pass electrical charge through the material, possible by either ohmic conduction or dielectric breakdown. The mechanism by which this layer enhances the effective contact resistance versus pressure is not fully understood.

In addition to the effects of enhancing materials used in the present invention to affect the contact resistance, advantage is made of the change in contact area upon that resistance. For example, as finger pressure against the sensor is increased, the finger flattens and brings more area into contact on and within the sensor. As the contact area increases, the contact resistance decreases.

Embodiments of the invention are now described, by way of example, with reference to the accompanying drawings, wherein:

Figure 1 is a graphical representation of the typical effective resistance generated by the pressure/force applied to the sensor of the present invention (Curve B) as contrasted with a sensor not using an enhancement material (Curve A);

Figure 2 is a layout of a typical construction of a base unit showing the electrodes and system for applying voltages to those electrodes for use in one embodiment of the present invention;

Figure 3 is an exploded view of a device constructed according to the embodiment of Figure 2;

Figure 4 is a schematic drawing of the sensor of Figure 2 showing means for determining coordinate position and contact pressure/force; and

Figure 5 is an exploded view of another embodiment of the present invention in which two resistive sheets are utilized for the generation of X- and Y-coordinate signals, and the enhancement material is placed between the sheets in order to generate the Z-axis (pressure/force) signal.

It is well recognized that the resistance between two surfaces loosely in contact can be reduced by pressing these surfaces together, and that the degree of reduction is related to the area of contact and the force/pressure value. This effect can be observed in conventional touch sensors. However, this change of resistance is very abrupt upon the application of a finger or other object applied to the sensor during

generation of X- and Y-coordinate signals. That change is illustrated in Curve A of Figure 1. Plotted therein is the effective resistance between the two surfaces of the sensor as a function of applied finger pressure. The effective contact resistance, R_{open}, is typically greater than 1 megohm when the sheets are separated or lightly in contact without finger pressure. It may be seen that with a small pressure (e.g. 8-15 oz/in^2) the effective resistance passes through a high threshold value (typically 10-50 Kohm) to a "closed" value of nominally less than 10 Kohm. The exact threshold levels are set by a controller in the associated circuitry. The high threshold level is nominally utilized to begin the taking of coordinate signals. Because the finger cannot recognize the difference in this small pressure range (but large resistance range), there can be no discrimination of the pressure level in what is referred to herein as a Z-axis signal.

Now referring to Curve B of Figure 1, plotted is an "enhanced" effective resistance curve as a function of applied finger pressure. It may be seen that relatively light pressures again produce a reduction of the effective contact resistance from the open value to the high threshold value. As stated above, this threshold pressure is suitable to obtain the X-, Y- and Z-coordinate signals. However, considerable extra force is then required to approach the "closed" value, i.e., the change in the effective contact resistance is reduced relative to the amount of pressure/force. The sensors according to the invention achieve this enhanced characteristic whereby a valuable Z-axis signal is producible upon application of this further pressure while continuing to obtain the X and Y

signals. If the slope of the curve between the threshold value and the closed value is sufficiently lowered, with suitable electronic circuitry a multiplicity of levels can be identified as a function of pressure.

Although typical values are given relative to Curve A and B, the actual values for any specific sensor depend considerably upon the materials of construction and the setting of a sensor controller. All the response curves, however, will be similar in shape. If the contact resistance is a part of a signal generating circuit as discussed hereinafter, a decrease in the resistance provides an increase in the resultant output signal.

Referring now to Figure 2, shown therein is one embodiment of a base unit 10 for a sensor according to the present invention. A substrate 12 is provided typically in the form of a printed circuit board (PCB). Any suitable opaque or transparent substrate, as well as a rigid or flexible substrate, however, can be used. Spaced inwardly from each edge of the PCB are a plurality of contact pads or electrodes 14. A diode 16 is provided for connection to each of the pads 14, with the opposite end of each diode being joined to appropriate connecting traces 18,20, as shown. These traces 18,20 terminate in terminals 22,24, respectively. A third terminal 26 on the PCB 12 is shown: this is for a purpose described hereinafter. The area to be active for the touch sensor is identified by a dashed line 28. This construction is substantially state-of-the-art, and persons skilled in the art will recognize the need for an appropriate

number of pads (and diodes), and their spacing, for particular applications. Furthermore, it will be recognized by persons versed in the art that resistive electrodes, in contrast to those illustrated, can be used such as those described in aforementioned U.S. Patent No. 3,798,370, or in application No. corresponding to U.S. patent application Serial 685,348 (our ref. ELG008). Also, as discussed hereinafter, a sensor using two sheets of resistive material can be employed in the present invention.

An exploded view of one embodiment of the sensor of the present invention is illustrated in Figure 3. The aforementioned base 10, as shown in Figure 2, is illustrated with only the substrate 12 and the electrodes 14 as shown thereon. The diodes, the connecting traces, and the connector pins are not shown for simplicity in this figure. Deposited upon the substrate 12 is an electrically resistive coating 30, such that the coating 30 contacts the electrodes 14. This resistive coating has a uniform resistance in the range between 50 and 20,000 ohms per square. Typically the value is about 100 ohms per square. The coating is typically applied using Electro-Science Laboratories, Inc.'s ink Type RS-16112 applied in any suitable manner to the substrate 12.

On top of this resistive coating 30 is applied a high resistive grid 32 made up of a rectangular array of narrow strips 34 which define small open spaces 36. The resistivity of this grid is chosen to be substantially greater than that of the resistive coating, e.g. by a factor of 1,000 or greater. the material for this resistance grid is a polymer thick

film such as Acheson Colloids Company's ink Type PTF-500 with a small amount of PTF-502 to produce a resistive grid having a resistivity greater than about 30K ohm-cm. This grid can be produced by any suitable means such as a silk screen process. This manner of applying the resistive coating 30 and the grid 32 to the substrate 12 causes these three portions to be a unitary item as illustrated by the bracket 38.

Spaced above the unit 38 is a contact sheet 40. This contact sheet is made of a flexible member 42, such as a sheet of rubber of other elastomer about 0.020 to 0.025 inch thick, or a plastic sheet about 0.005 to 0.015 inch thick, having applied thereto a conductive coating 44 on a face toward the grid 32. This conductive coating 44 also has elastomeric properties and may be produced using Emerson and Cuming, Inc.'s Eccocoat 258A applied to the sheet 42. It will be understood, also, that the aforementioned resistance grid 32 can be applied to the surface of conductive coating 44 rather than the resistive layer 30, if desired.

The contact sheet 40 can be attached using a frame-like layer 46 defining a central opening 48 which corresponds in size with the active region 28 indicated in Figure 1. This attachment typically has a thickness of about 0.005 inch and is typically formed of an acrylic type adhesive whereby the contact sheet 40 is bonded around the periphery thereof to the unit 38. A light contact between the conductive coating 44 and the high resistance grid 32 may not be detrimental for some applications. However, if full separation therebetween is desired, this can be accomplished by conventional

separators such as the dot separators shown in U.S. Patents No. 3,911,215 or 4,220,815.

For practical operation, it is usually desirable to have a surface to be contacted by a finger or other object having a different texture than a sheet 42. For this reason, this embodiment of the present invention is provided with an overlay sheet 50 which can be, for example, a sheet of about 0.010 inch polycarbonate or polyester plastic. This overlay sheet 50 is attached to the periphery of the sheet in any suitable manner, or can be bonded over the entire upper surface of the sheet 42.

A schematic diagram of the touch panel assembly (of the embodiment illustrated in Figure 3) and appropriate electronics is shown in Figure 4. Only those portions of the touch panel assembly which influence the operation of the system are shown for simplicity. For example, the substrate 12 is shown upon which the resistive layer 30 and the resistance grid 32 are indicated as 30/32. Furthermore, the conductive sheet 44 of the contact sheet 40 is illustrated but in an exploded view. The contact 26' at the edge of the conductive layer 44 corresponds electrically to the terminal 26 on the substrate as shown in Figure 2. In this embodiment, the terminal 22 is connected to switch 52 through lead 54. Switch 52, as indicated, provides for selectively applying either a low voltage for the X-coordinate potentials or a high voltage for the Y-coordinate potentials in the resistive layer. In a like manner, terminal 24 is connected to a switch 56 through lead 58. Switch 56 provides for the selection of either the high voltage for the X-coordinate

potentials or the low voltage for the Y-coordinate potentials. Generally the low voltage for both the X- and Y-coordinate potentials is zero. A conventional source of these voltages, and a sequencer for operating the switches, is shown at 60.

Terminal 26 (and thus 26') is connected to an operational amplifier 62 through lead 64. The output from the operational amplifier 62 is fed to an analog-to-digital converter (ADC) 66. The ADC can be connected to a digital comparator 68. The input to the operational amplifier 62 is also connected through resistor 70 and switch 72 to a fixed selected voltage V_0 for purposes discussed below relative to the operation of the system.

The operation of this embodiment of the present invention can be described and best understood using a typical point P for contact of the sensor (see Figure 4). A contact point CP is created between the conductive layer 44 and the combined grid/resistive layer (30/320. The grid has the same potentials as the resistive layer so that contact with the resistive layer is not required to obtain the X- and Y-coordinate signals. During time intervals for the determination for the X- and Y-coordinates of point P, switch 72 is open and switches 52 and 56 are set for applying appropriate potentials in either the X or the Y direction within the resistive layer 30 in a normal manner. The individual voltage signals related to X- and Y-coordinates of point P (i.e., CP) are thereby applied to the input of the operational amplifier 62 by way of the terminal 26,26' and lead 64. These signals are then transmitted via amplifier 62 to the

analog-to-digital converter 66 for digitizing, display, and use in any suitable manner. The operation of the switches 72, 52, and 56 are controlled in proper sequence by the voltage supply-sequencer 60 or corresponding circuitry.

During another time interval using this embodiment of the present invention, the switch 72 is closed and the switches 52 and 56 are moved to their low position which is, as stated above, conventionally ground potential. With the switches in this condition, the voltage presented at the input to the operation amplifier 62 is that at point 72 in a voltage divider network, with one side of this network being resistor 70 (supplied by fixed voltage V_0), and the other side made up of a sum of the resistance shown on the touch panel assembly schematic. Specifically, these are resistances R_{CS} (which is the resistance from the contact point to the terminal 26'); R_S (which is the resistance from the contact point on the resistive layer and grid 30,32 to the terminals 22 and 24); and R_C (which is the variable effective contact resistance between the conductive layer 44 on the contact sheet 40 and the unit 38, namely the resistive layer 30 and/or the grid 32. The voltage established by this voltage divider at juncture 72 is applied to amplifier 62 and then processed by the analog-to-digital converter 66 and transmitted to any host device as the Z-coordinate (pressure/force related) reading. As stated heretofore, a decrease in the value of the effective contact resistance is reflected by an increase in the Z-coordinate signal. The digital comparator 68 shown in Figure 4, which receives the signal from the analog-to-digital converter 66, is used between the X,

Y or Z readings to monitor the open or closed circuit conditions between the contact sheet 44 and the unit 38 in order to determine proper operation of the present touch panel.

The circuit components in Figure 4 contained within the electronics portion(s) of the figure, including the switches, are all conventional devices. Specific commercial units for these applications would be well known by persons skilled in the art. They can be singular electronic units or can be combined in various configurations to accomplish the same functional results as stated above.

Referring now to Figure 5, shown therein is an exploded view of another embodiment of the present invention. All components serving the same function as in the embodiment of Figure 3 carry the same identifying number. For example, the cover sheet is made up of an elastomer sheet 42 and there is a top sheet or overlay 50. It also can utilize a substrate 12. As in Figures 2 and 3, this substrate can be an elastomer if desired.

In this embodiment the coordinate signals are produced using a pair of spaced apart resistive sheets 74,76. Electrodes 78,80 along opposite edges of resistive sheet 74 provide for the application of voltages via leads 92,94 to the sheet. In a like manner, electrodes 82,84 are in contact with the opposite edges of resistive sheet 76 whereby orthogonal fields (relative to those in sheet 74) can be generated by applying appropriate voltages via leads 88,90. A frame-shaped mounting material 48, as in Figure 3, is shown between sheets 74 and 76. As discussed with regard to Figure

3, if desired, appropriate separation means (not shown) can be used to prevent inadvertent contact between the resistive sheets 74,76. The resistive sheet 76 can be an integral part with the elastomer sheet 42 and overlay 50, and the resistive sheet 74 can be an integral part with the substrate 12.

The "grid" (or other appropriate distribution) of high resistance material 32 is shown in this figure as applied to the surface of resistive sheet 74 facing the second resistive sheet 76. In this manner, it is contacted by the second resistive sheet 76 whenever pressure/force is applied to a point on the overlay 50. Alternatively, the high resistance material 32 can be applied to the underside of resistive sheet 76 facing resistive sheet 74. This embodiment functions essentially the same as the embodiment of Figure 3 and the circuit diagram of Figure 4 except for the two-sheet X and Y voltage applications.

The enhancing material used in the embodiments specifically described may be an array of material having a resistivity more than 1000 times that of the resistive sheets or layer on either side of the array.

Using the embodiment of Figure 3 as an example, the array 32 of high resistance material functions in at least one of two ways. Initially under light pressure from a finger, only the highly resistive array 32 is contacted by the contact sheet 44. This highly resistive array is of the same voltage level as the underlying lower resistive coating 30 and the X- and Y-coordinate information is obtained. As pressure is increased, the contact sheet 44 is pushed through the

array and into direct contact with the lower resistance coating 30, resulting in a drop in the effective contact resistance and the production of a Z-axis signal. Alternatively, or in combination, the Z-axis effect also occurs even if the high resistivity array 32 spacing is such that the contact sheet 44 is not pushed through the array at these substantial finger pressures.

From the foregoing, it may be seen that a position sensitive device has been described having Z-axis capability i.e., provides a signal related to applied pressure/force. This device achieves this capability with a simplified construction thereby producing an accompanying reduction in cost over devices in the prior art designed to accomplish similar results.

CLAIMS

1. An electrographic sensor for generating signals corresponding to the two dimensional coordinates of a contact point on the sensor, the sensor being capable of generating signals related to the pressure/force applied at the contact point, and comprising:

1) a resistive sheet and a further sheet positioned proximate each other, such that the perimeter of the further sheet substantially conforms to the perimeter of the resistive sheet, and such that inner surfaces of the sheets face each other, each of the sheets

a) being capable of having electrical fields introduced therein, and

b) extending across the sensor,

and the further sheet being adapted to move towards the resistive sheet upon the application of pressure/force, to the sensor, at the contact point;

2) means for generating orthogonal electrical fields within the sensor, in the X and Y directions, such that signals corresponding to the X- and Y-coordinates of the contact point are produced when electrical connection is made between the sheets at the contact point; and

3) enhancing means interposed between the sheets, which determines an effective contact resistance between the sheets which varies inversely with the pressure/force applied, in a manner which differentiates between levels of pressure/force applied at the contact point such that a signal corresponding to the Z-coordinate can be obtained, the Z-coordinate-signal being related to the magnitude of the pressure/force at the contact point.

2. A sensor according to claim 1, wherein at least one of the sheets is elastomeric.

3. A sensor according to claim 1 or 2, wherein the resistive sheet is an elastomeric layer provided with a resistive coating on its inner surface.

4. A sensor according to claim 3, comprising electrodes in contact with the resistive coating for receiving voltages to introduce the said electrical fields in the resistive layer, which electrodes preferably comprise a plurality of contact electrodes, spaced along the periphery of the resistive sheet, and in contact with the resistive coating.

5. A sensor according to claim 1 or 2, wherein each of the sheets is provided with a resistive layer on its inner surface, and with electrodes positioned along opposite edges of the sheet in contact with the respective resistive layers, the electrodes of one of the resistive sheets being oriented orthogonally with respect to the electrodes of the other sheet.

6. A sensor according to any one of claims 1 to 5, wherein the enhancing means comprises

(a) a distribution of a material having a resistivity which is substantially greater than the resistivity of the resistive sheet: preferably

(i) a grid array of a resistance material which is applied to the inner surface of the resistive sheet, the resistance material having a resistivity which is at least 1000 times greater than the resistivity of the resistive sheet, or

(ii) an insulating powder interposed between the sheets, or

(iii) a layer of lacquer paint, having a thickness of about 500 to 5000 Angstroms, applied to the inner surface of one of the sheets; or

(b) a distribution of a material having a resistivity which is substantially greater than the resistivity of the resistive layers on the sheets; or

(c) a plurality of spaced-apart buttons, made of an insulating material, and applied to the inner surface of one of the sheets.

7. An electrographic touch sensor for generating signals corresponding to the two-dimensional

coordinates of a contact point on the sensor, the sensor being capable of generating signals related to the pressure/force applied at the contact point, and comprising:

1) means for generating orthogonal electrical fields within the sensor having

   a) a uniform resistive layer, to accept voltages to produce the orthogonal fields, and

   b) at least one exposed surface, the field-generating-means being adapted to generate the output signals of two-dimensional coordinates of the contact point when the sensor is contacted;

2) an array of high resistance material applied to the exposed surface of the field-generating-means, and having a resistivity substantially greater than the resistivity of the resistive layer of the field-generating-means, the array having a predetermined configuration and covering a predetermined portion of said exposed surface; and

3) a conductive sheet, having a first surface and a further surface, positioned proximate said array with its first surface towards the array;

whereby when a pressure/force is applied to the sensor at the contact point it causes the first surface of the conductive sheet to make contact with the array and thereby generates signals corresponding to the two-dimensional coordinates of the contact point, and a signal corresponding to a third coordinate, which third coordinate is related to a change of the effective contact resistance between the resistive layer of the potential generating means and the conductive sheet at the contact point, as enhanced by the array.

8. A sensor according to claim 7, wherein the means for generating the orthogonal electrical potentials comprises a layer of uniform resistivity, provided with spaced-apart electrodes in contact with the layer, arranged along the perimeter of the layers, and adapted to receive voltages, the resistive layer being applied to a supporting substrate.

9. An electrographic touch sensor for generating signals corresponding to the X- and Y-coordinates of a contact point on the sensor, and being capable of generating signals related to a pressure/force related Z-coordinate of the contact point, which comprises:

1) a substrate;

2) a uniform resistive coating applied to the substrate;

3) electrode means in contact with the resistive coating proximate the perimeter edges of the coating, whereby orthogonal electrical fields can be generated in the coating upon the

application of voltages to the electrode means;

4) an array of material applied to the resistive coating, having a resistivity substantially greater than the resistivity of the resistive coating, and having a selected configuration; and

5) a flexible conductive sheet, having a first surface and a further surface, proximate the array with said first surface towards the array;

whereby when a sufficient pressure/force is applied to the further surface of the conductive sheet at the contact point it causes contact of the first surface of the conductive sheet with the array of material and thereby generates signals in the conductive sheet corresponding to the two-dimension coordinates of the point, and independently generates a signal in the conductive sheet corresponding to a reduced contact resistance between the first surface of the conductive sheet and the resistive coating, which is a function of the pressure/force applied at the contact point and is thus a function of the third coordinate.

10. A sensor according to claim 9, wherein the array comprises perpendicularly oriented lines of high resistivity material defining rectangular open areas between said lines, or a resistance layer provided with substantially circular openings, or a distribution of an insulator material.

11. A sensor according to claim 9, further comprising:

4) voltage supply means;

5) sequencing means for connecting the voltage supply means to the electrode means to generate the orthogonal fields in said uniform resistive layer;

6) circuit means for receiving and processing the signals introduced into the conductive sheet corresponding to the X- and Y-coordinates of the contact point; and

7) further circuit means for receiving and processing the signal introduced into the conductive sheet corresponding to the pressure/force and thus to the Z-coordinate of such contact point.

12. A sensor according to claim 9, wherein the electrode means comprises:

(a) a plurality of contact pads spaced along each of said perimeter edges;

(b) a plurality of diodes, each of said diodes having a first lead connected to one of said contact pads and a further lead;

(c) trace leads connected to appropriate of said further diode leads; and

(d) terminals on said trace leads for the application of said voltages to said contact

pads for said generation of said orthogonal electrical fields in said resistive coating.

13. A method for obtaining a signal corresponding to the pressure/force applied to an electrographic touch sensor at a selected contact point, the sensor comprising a pair of closely disposed layers, at least one of which comprises a resistive layer having a uniform resistivity value; the sensor being adapted to provide signals corresponding to the X- and Y-coordinates of the contact point, the method comprising:

1) applying a distributed array of an enhancing material between the layers, the resistivity of the material of the array being substantially greater than the resistivity of the resistive layer;

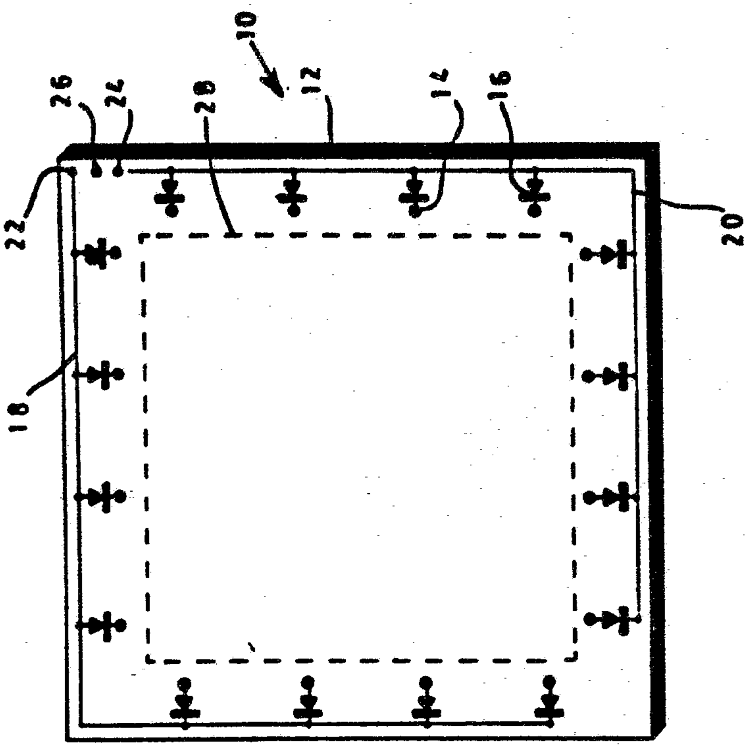
2) generating orthogonal electrical fields in the sensor;

3) obtaining signals generated in the layers corresponding to such X- and Y-coordinates upon applying such pressure/force at such selected point; and

4) obtaining a further signal, generated during a separate time interval, related to a change in effective contact resistance between the layers upon application of the pressure/force at the contact point, the further signal increasing as a function of the pressure/force applied to the sensor at the point as the

effective contact resistance is reduced upon an increase in the pressure/force.

* * * * * * * *


10
12
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28

Fig. 2

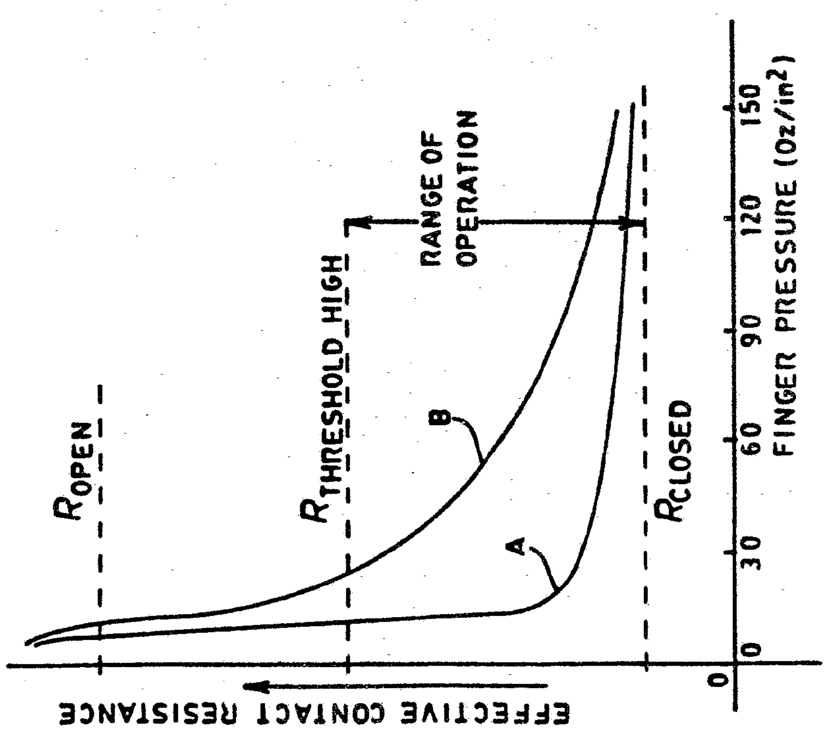

EFFECTIVE CONTACT RESISTANCE
R_{OPEN}
$R_{THRESHOLD\_HIGH}$
R_{CLOSED}
RANGE OF OPERATION
A
B
0
0
30
60
90
120
150
FINGER PRESSURE (Oz/in²)

Fig. 1

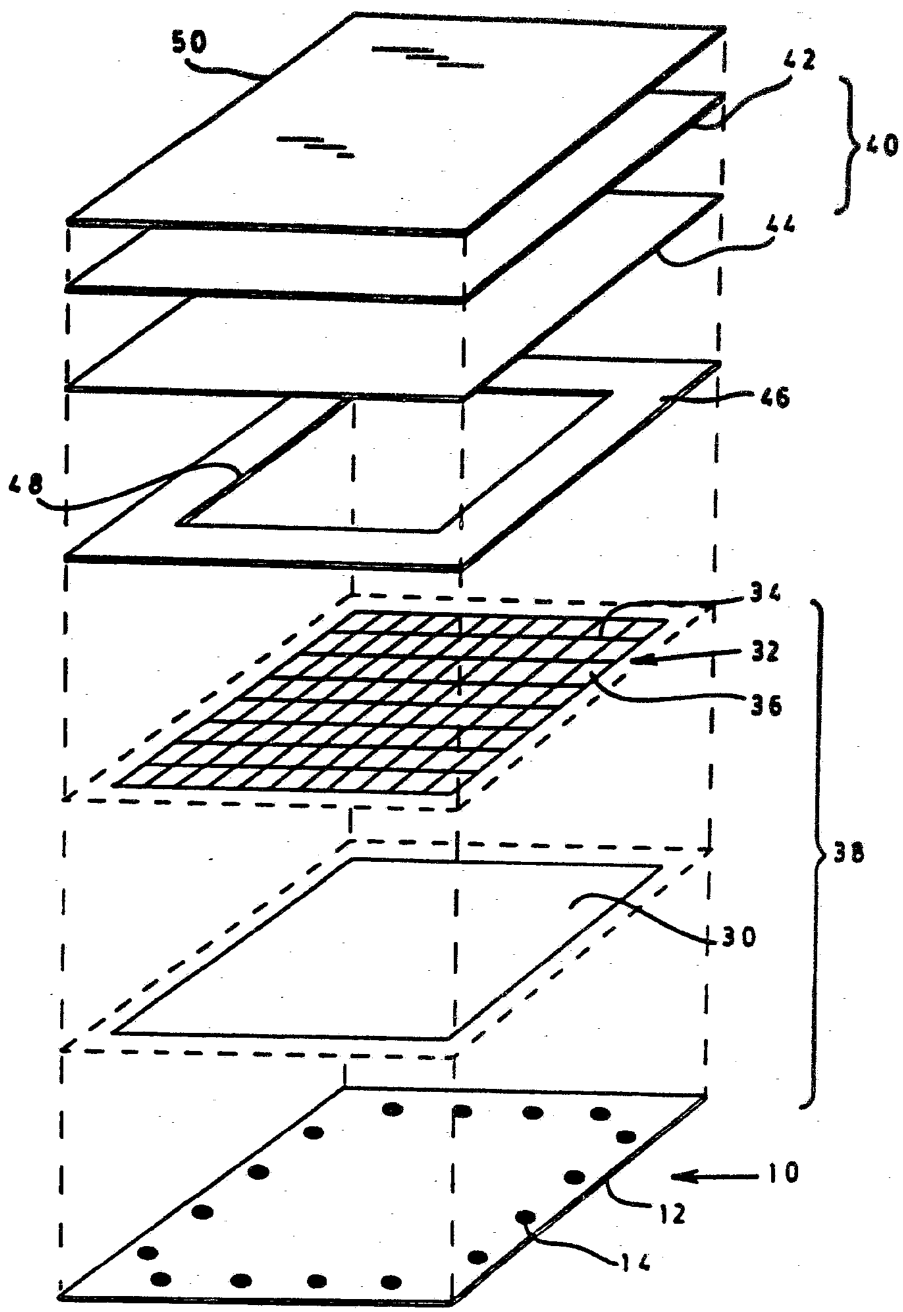
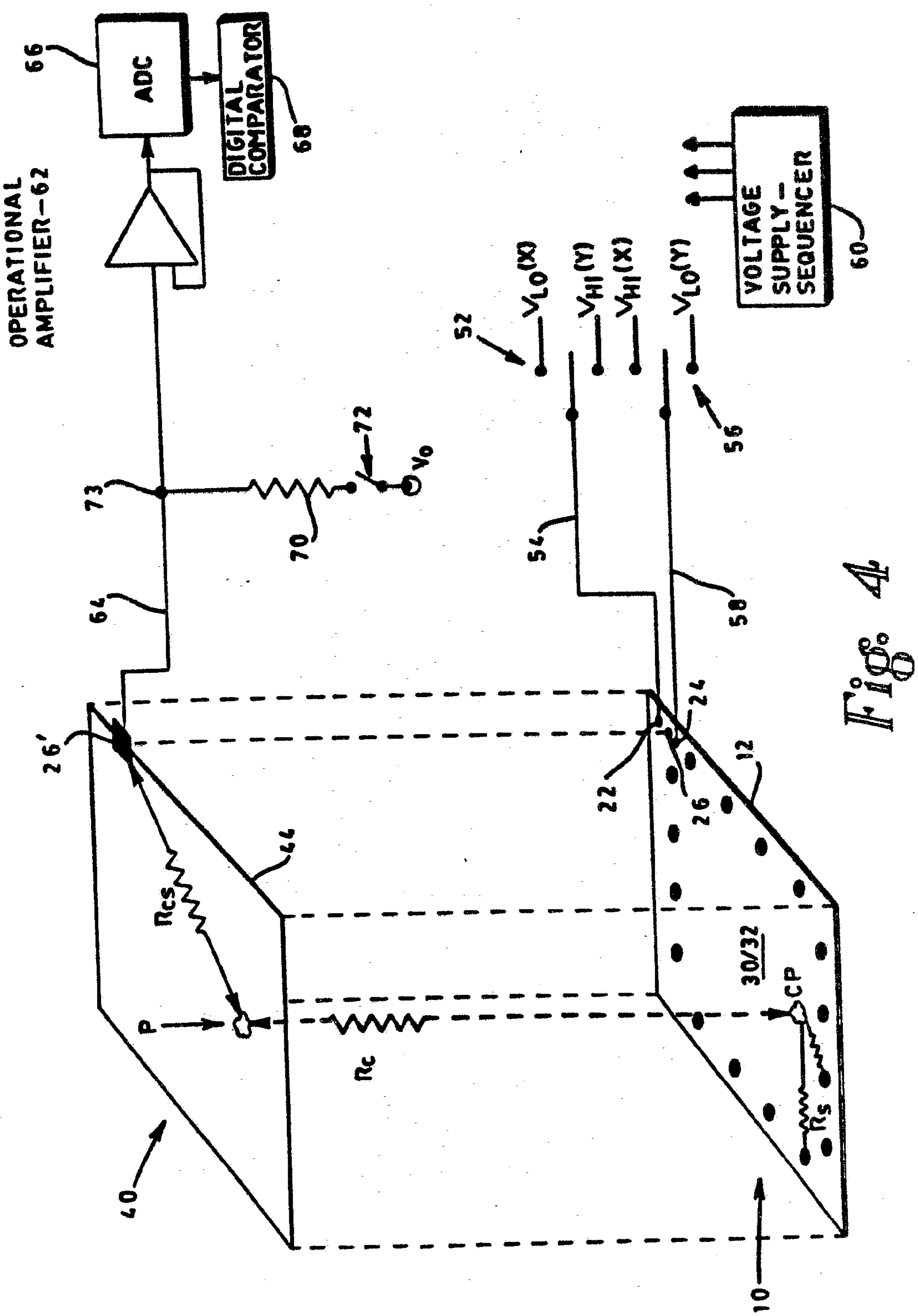


Fig. 3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ADC
DIGITAL COMPARATOR
68
73
72
V_0
70
64
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44
P
R_C
40
52
$V_{LO}(X)$
$V_{HI}(Y)$
$V_{HI}(X)$
$V_{LO}(Y)$
56
VOLTAGE SUPPLY-SEQUENCER
60
54
58
24
22
26
12
30/32
CP
R_S
10

Fig. 4

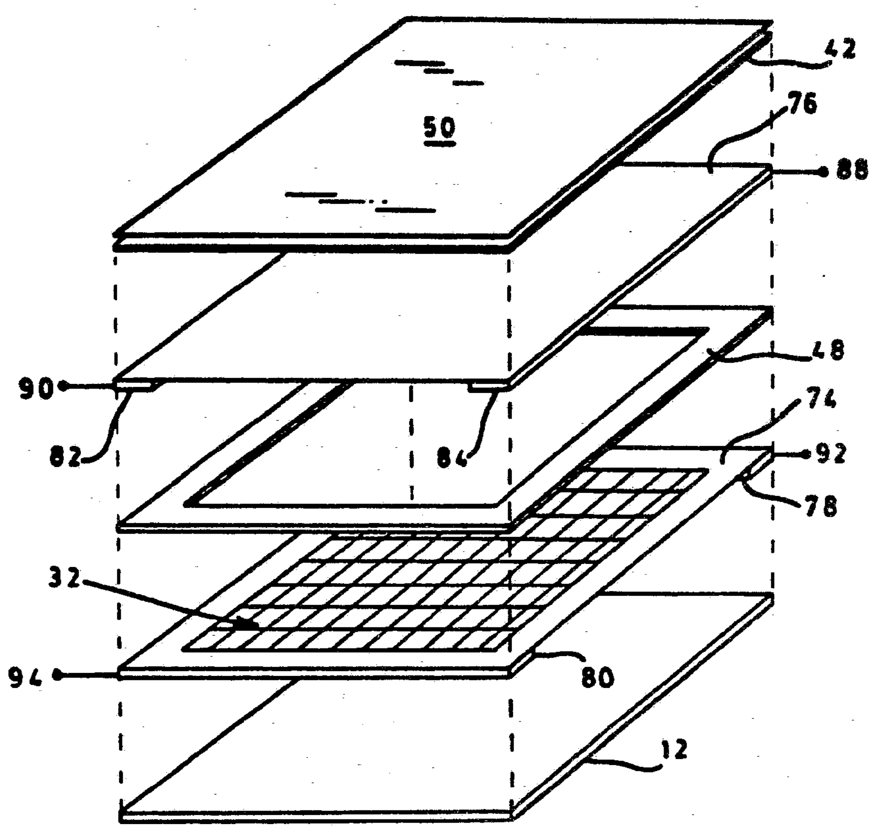

Fig. 5